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Investigations on the Restorations of Erased Engraved Marks on Steel Surfaces

Dissertation submitted in partial fulfillment for the Degree of Bachelor of Science in Forensic Science

MOHD AZLAN BIN MOHD ZAILI

School of Health Sciences
Universiti Sains Malaysia
Health Campus
16150, Kubang Kerian, Kelantan
Malaysia

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CERTIFICATE

This is to certify that the dissertation entitled

Investigations on the Restoration of Erased Engraved Marks on Steel Surfaces

is the bonafide record of research work done by

Mr. Mohd Azlan b Mohd Zaili

during the period of 27th December 2005 to 25th April 2006 under my supervision.

Signature of Supervisor : .....

Name and address of Supervisor : P.M.DR. R. KUPPUSWAMY Pensyarah Pusat Pengajian Sains Kesihatan Universiti Sains [illegible]

Date : .....

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ABSTRACT

Restoration of erased engraved marks is considered difficult compared to the restoration of stamped marks, as the deformation occurring to the metal due to the engraving is minimal. Hence a series of experiments was designed to test the sensitivity and efficacy of different metallographic reagents that are traditionally used on steel surfaces to reveal erased stamped marks.

The experiments consisted of preparing several steel plates with engraving marks and erasing these engravings marks to different levels down to the depth of engraving. Then some selected reagents were used on them using swabbing technique to restore the erased engraved marks. The results have shown that the reagents of 5g cupric sulphate ($CuSO_4$), 60 ml hydrochloric acid (HCl), 30 ml concentrated ammonium solution (NH_3OH), 60 ml water and also 5g cupric chloride ($CuCl_2$), 50 ml hydrochloric acid (HCl), 30 ml water (H_2O) are quite sensitive and effective in the recovery process of erased engraved marks.

It is also noted during these experiments that the disturbance caused to the steel surfaces occurring to original engraving has penetrated just through 0.04 mm below the bottom of the engraved marks.

INTRODUCTION

A problem of frequent occurrence in forensic science is the restoration of erased identification marks on items of evidence. These marks may be the serial numbers on the chassis or engine of a car or on a gun and other identification marks on jewellery and antique items. The serial numbers are placed on many manufactured objects and hence they provide an easy means of distinguishing one from another. Serial numbers may consist, individually or in combination, of numerals, letters, or symbols. Unless special precautions are taken by the owner, serial numbers are frequently the only method of establishing ownership.

In many cases property can be identified by the owner by its special peculiarity or by placing their own serial number or private marks on the articles to enable them to identify it. In cases concerning articles of common type which are not identifiable by their peculiarities, the articles are normally inscribed with a serial number which serves to identify them (L.C. Nickolis, 1956). Many articles having component parts, such as automobiles, weapons, and watches, bear serial numbers on several of the component parts. When these numbers are erased with criminal intent, the identification of the property poses problems.

In Malaysia, vehicle theft has become a major problem. Based on statistics from Royal Malaysian Police, the numbers of stolen vehicle has increased every year since 1997 and in year 2004 only, 65,076 vehicles including motorcar, lorry, van and motorcycle have been reported missing. From 1997 to 2003, only about 32 percent from total of 364,531 stolen vehicles have been recovered. In Malaysia, the stolen vehicle may be used in two ways, either they are sold in whole or the parts will be detached and will be sold as spare parts. For vehicles which are sold as whole, their original numbers will be obliterated and new identification numbers will be given. It will be then sold either locally or to other neighbouring countries like Thailand, Indonesia and Singapore. There are also cases where the stolen vehicles are given new serial numbers from a previously wrecked vehicle of similar type, so that it can be used like normal legal vehicle since the wrecked vehicle is legally registered to be used. Beside that, statistics from Royal Malaysian Police also shown that property crime has increased from 2002 to 2004 and only about half of the reported cases could be solved so far. Similarly, the serial number of a firearm places a very important role in tracing the origin of a gun recovered from a crime scene. Thus, in case of vehicle theft and other crime involving a gun or other valuable items, where identification marks are erased or obliterated, it becomes necessary to restore the original marks. Fortunately, scientists have developed many useful techniques to reveal the marks that have been erased or obliterated. These techniques enable the latent impression in the plastically deformed region below the depth of the stamped marks to appear.

Type of Markings

There are several common methods used by manufacturer to place serial numbers of on their products including;

a) Stamping

The majority numbers are still punched numbers produced by stamping the numbers into the metal by striking a die bearing the number forcibly into the metal with hammer. As a result, there is a depressed number produced in the metal and underneath the contours of the number there is compressed and distorted metal which has different physical properties from those of the bulk metal. Manufactures always use a group of punches together assembled in a block, the number being increased by one with each succeeding component. When the number is stamped on the metal surface, plastic deformity occurs beneath the visible indentation. The plastic deformity causes the impression to remains even after the force causing it has been removed and the metal permanently has been strained.

b) Engraving

There are generally two types of engraved marks commonly encountered: those made with an engraving tool and those made with an electrical engraver. The first type of mark is found on antiques articles, plated articles and jewellery, while the second is used for engraving identification numbers on common articles such as motor car chassis, firearms and also on very hard metals like stainless steels and tool steels. Engraved marks are usually small and shallow incised marking made by removing the metal with the tools. As the underlying metal is not seriously disturbed, the erasure of such markings is usually

effective and restoration is often difficult. There is another type of engraving technique which has become popular recently in which it uses laser to engrave the metal surface known as laser engraving. In this type of engraving, a laser beam of high intensity is focused through a lens to the metal surface. This high-powered focused beam of light has enough energy to vaporize the material surface thus producing a visible mark on the material. Laser etching produces no pronounced sub-surface deformity such as crystalline structure dislocation that is normally produced by stamping impression. Instead laser etching leaves a slightly thermally altered area around the impression called Heat Affected Zone (HAZ) of a few microns (0.00008 to 0.0001 of an inch) (Gregory S. Klees)

c) Casting

These are commonly raised above the surface though sometimes depressed. They form part of the mould used in casting and therefore appear on the casting. These numbers are used to identify the particular casting employed. They do not identify the whole article for example; the crank case of a motor engine will bear a cast number for a particular case. These numbers do not identify the engine as a whole. This is very unfortunate because when a cast number is filed away, it is not possible to restore it.

Methods of Obliteration of Identification Marks

When a thief steals numbered articles, he always takes steps to remove the identification numbers from it with the hope that the recovered item can neither be recognised nor be proved to be stolen (P.B.Wilson, 1979). There are several ways commonly used by the criminals to erase or obliterate the serial numbers which include the following;

Filing and Grinding

It is done by simply removing the numbers by hand filling or grinding with a high speed carborundum grinding wheel. This is often followed by polishing and then over stamping with a new number.

Over-stamping

This is done by simply stamping a new number over the old. For numbers with curved surface (e.g. 2, 3, 5, 6, 9 and 0) the 8 stamp is the one most chosen. For numbers with straight surface (e.g. 1 and 7) the 4 stamps is the obvious choice. Serial numbers with a preponderance of '8' and '4' should be treated with suspicion.

Centre Punching

This technique is done by fully obliterating the numbered surface with a pointed punch in order to hide or distort the whole numbered surface.

Drilling

In this technique, the numbers and the surrounding metal will be completely removed using a drill. The hole left will then filled up with lead solder or weld material or other filler in order to hide the distortion left.

Welding

This is done by heating the surface until the metal flows with either an oxy-acetylene or an arc-welder.

Of the above five methods used to remove the punched serial numbers, only grinding and welding will permanently remove all recoverable traces of the original numbers. With drilling, unless it is very superficial, the altered crystalline structure will be removed and so will any recoverable traces of the numbers.

Centre punching can, depending upon the area of the serial number recovered and the force applied to the punch, makes it extremely difficult to interpret any restored number. The problem here is that the centre punching will alter the crystalline structure itself. Any restoration performed will restore the centre punching marks as well as the serial number. One overlaid upon the other results will present an extreme confusing pattern of mark to decipher.

Applying an oxy-acetylene torch or arc welder, until the metal flow, will also permanently remove all traces of the crystalline structure. In this case the metal is being remelted and the crystalline structure allowed to reform into a completely new and uniform pattern on cooling. Thus, the original crystalline structure together with the altered structure pattern formed by punching will have been completely lost.

REVIEW OF LITERATURE

There are a lot of studies that have been made regarding the recovery of obliterated serial numbers on metal surface. These studies were conducted in order to understand more about the principles and theory behind the recovery and obliteration process, the metallurgical aspect and several physical and chemical methods to restore the erased numbers.

L.C. Nikolls (1956), in his book discussed several ways that normally have been used to place markings on items including casting, engraving and punching. He has also listed several methods of treatment to restore the obliterated serial numbers on several different surface including stainless steel, iron, cast steel, copper alloys, aluminium alloys, pure metals, wood, plastics and leather. He added that the depth of distorted or altered material is necessarily very small. It would not exceeded 1 millimetre in metal, maybe somewhat more in wood and less in leather. The impression that is punched by hands will cause unevenness of the depth of impression not only from letter to letter but also in different parts of a single letter. Inevitably, some portions of the lettering will be erased below the depth of alteration and nothing remains which is capable of being restored.

Polk and Giessen (1975), have discussed the metallurgical background of the serial numbers mark, in order to understand more about the deformation and alteration of the metal when it is obliterated. The atoms within metals have crystalline arrangement known as grain which is densely packed together to fill spaces. When force is initially applied, the metal first becomes elastically strained and will return to its initial shape. If more force is applied, the crystalline structure will move and will produce permanent change of shape. When a serial numbers is placed on a metal surface, i.e. by stamping, the force is sufficient to deform the metal so as to leave behind an impression. The number consists of a visible indentation, a plastically deformed region surrounding the indentation and an elastically strained region bordering the plastic region. The plastic region has deformed so that the metal at the area has been pushed to the side and above the original surface. The elastically deformed region is material which was further from the puncher and did not experience a force great enough to produce plastic flow. However, the elastically deformed region is constrained from relaxing back to its original condition by opposing force in the adjacent plastic region which has undergone a permanent change of shape. They also added that the amount of plastic flow and the depth to which the plastic region extends below the indentation depend upon the shape of the puncher and the depth of the indentation where blunter puncher will produce plastic flow to a greater depth than sharper V-shaped punchers. These authors also discussed chemical serial number recovery methods. In these methods an acid solution shows preferential between the deformed and unreformed region of the metal.

Wilson P.B, (1979) have reviewed the metallurgy and the principle behind the restoration process and he had reported some successful case of the restoration of erased stamped marks using chemical etching.

Heat also can be used to recover the obliterated serial numbers, as described by Susan L. Maxwell (1993) in her work at Scientific Section of Queensland Police Service. This technique is based on the fact that various phases present in a polycrystalline metal will display different behaviour when subjected to heat. In this technique, the iron metal surface is firstly cleaned and polished to a mirror like finish. Then the surface is treated with direct heat of 3500°C flame from a welding oxy-acetylene torch until the obliterated number is visible. The number will be appear when the steel is red hot and will rises slightly above or drops below the treated metal surface. Then the metal is allowed to cool before it is slightly polished with fine grade sand paper to remove the resulting deposited oxide and the restored number will appear lighter in colour than the surrounding metal surface.

Recovery of erased numbers on surface other than metal such as polymers has also been demonstrated to be successful as conducted by Horst Katterwe (1993). Experiments on different polymers showed that swelling and polishing rates and also thermal properties were different for deformed and unreformed regions of the polymers in which this process could be used for the restoration of erased numbers. The experiment conducted successfully revealed the thermomechanically treated regions of polymers that possess a higher swelling capacity under the influence of solvents than untreated the region. During the swelling process, a widening of the macromolecule's cross-linked structure occurs and final state is reached when no further swelling occurs. The successful experiment showed that polymers possess a "mechanical memory" in which the polymer's molecules are able to raise the entropy of the colloidal structure to the highest possible value and the sample returns to its original shape.

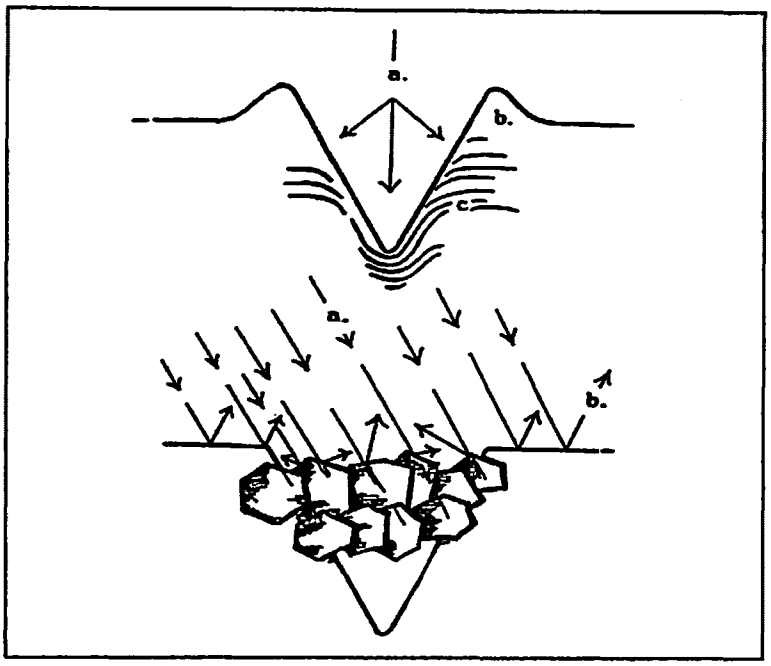

Figure 1 : An illustration of the grain structure disturbance in a metal plate. The stamped numbers is consists of: (a) visible indentation (b) plastically deformed region (c) elastically strained region

The works and studies conducted by Brian J. Heard (1997) discussed several methods that are normally used to erase serial marks on weapon including filling and grinding, peening, over-stamping, centre punching, drilling and welding. The works also discussed the theory behind the restoration process at which he stressed that any components made from metal or alloys are polycrystalline in structure, which mean that they are composed of an irregularly shaped aggregate of tiny crystal or grains. These form when the molten metal cools to the point of solidification. By regulating the cooling of the metal during manufacture, the size of the grain or crystals is controlled, thus affecting the mechanical properties of the metal. When a number is stamped into metal, the crystalline structure surrounding the numbers is distorted and the grain structure compressed and this will effectively reduce the size of the grain or crystal size of the metal and altering its physical and mechanical properties. The metal will then exhibit altered in hardness,

strength, magnetic, electrical and chemical properties in the immediate area surrounding the stamped number. Beyond the immediate area surrounding the stamped number, this effect becomes too dissipated to have any effect. If the surface is filled or ground down until the number has just been removed, the new surface will contain an area of altered crystalline structure that if correctly treated can be revealed. There are several methods that can be used to restore the obliterated serial numbers including chemical, electrolytic, magnetic particle, ultrasonic cavitation and also other methods. Chemical methods is the simplest and the most effective method used in the forensic science laboratory for restoring obliterated numbers in which an appropriate reagent is applied to the polished area with a cotton swab by rubbing action. Electrolytic method is a combination of electropolishing and electrochemical etching technique in which the specimen is made anode and a cotton swab containing the electrolyte solution becomes the cathode before an external DC voltage is applied to it. Magnetic particle method is a non-destructive technique of restoration. However, the specimen subjected to this method must be a ferromagnetic metal such as iron or steel. . In ultrasonic cavitation method, the specimen is immersed in an ultrasonic cavitation bath filled with water. This kind of bath will create vibrational bubbles. The number may be restored by the etching action of the cavitation bubbles. Other methods for obliterated number restoration included by the author are heat etching where it is done by heating the metal with an oxyacetylene torch to heat tint the surface, while other technique is by cooling the metal until water vapour frost forms on the surface.

Nalini Natarajan and M. Hemalatha (2003) have suggested a technique to enhancing the successful of the photographic process of the recovered serial numbers. They have stated that fluorescence powder, which is normally used in recovery of

fingerprint, can be used in the photographic enhancement process of recovered serial numbers. The recovered number is dusted with a thin layer of fluorescence fingerprint powder. A piece of clean cellophane tape is then pressed onto the surface of the thin layer of fluorescence fingerprint powder. The tape is then removed and mounted on a black lift card and photographed using orange filter under 450 mm illumination By using these procedure, the recovered numbers can be successfully photographed and the problem of camera accessibility to remote surface, especially in vehicles is overcome.

M. J. Johnson, C. C. H. Lo and L. B. Naidu (2003) develop a magnetic imaging technique for the non-destructive restoration of obliterated serial numbers. This is achieved by imaging the magnetic signatures that result from residual plastic deformation. They found, by scanning the Hall sensor across the obliterated serial numbers, it was possible to obtain a two dimensional image of the stray magnetic field distribution, and because of magneto-elastic coupling, this image contains information about the plastically deformed regions under the stamped characters and can therefore be used to reconstruct the serial numbers. The technique exploits the fact that stamping of serial numbers into a metal induces plastic deformation to regions beneath the imprinted characters that remain even after the surface layer has been removed and these deformed regions have magnetic properties different (lower permeability and hence a large magnetic reluctance) from those of the undamaged surroundings. Under a constant applied field, the spatial variations in magnetic properties disrupt the magnetic field distribution, which can be detected non-destructively using magnetic field sensors. By mapping the stray field over the obliterated serial numbers, a two-dimensional image showing the variations in the mechanical conditions can be obtained. This image can be used to identify the pattern of localized material damage, from which the obliterated serial numbers can be restored. However, the

problem aroused using this technique is the ability to resolve the serial numbers that are close together and the banding effect observed in which some regions of the specimen exhibit better contrast than others which is perhaps due residual magnetization or surface stress.

D. Utrata and M. J. Johnson (2003) conducted an experiment in order to define conditions that increased the likelihood that magnetic particle testing technique will be successfully applied in the recovery of obliterated serial numbers. The experiment also meant to understand the magnetic characteristics of different steels and how these affect the test results, such as varying results for carbon steels and alloy steels after different thermal and forming treatments.

Gregory S. Klees (2004) in his work regarding the restoration of obliterated laser-etched firearm serial numbers and barcode identifier found that it is very difficult to restore such marking type. This is because the process of removal of the metal by vaporization from intense heat to form a character impression leaves no pronounced subsurface deformation such as crystalline structure dislocation that is produced by stamping. In his work, he also found that, the restoration of such marking type can be done by using a reagent with low corrosive rate.

Thus, several methods are suggested in the literature to reveal the plastically deformed region once the numbers are erased or obliterated. The methods would however be successful provided the indentation marks are not too much erased, so that the deformed regions are still possible to be deciphered. Further, the literature does not give much information about the recovery of erased engraved marks. In the case of engraved

marks, not perceptible plastic deformity would be expected to occur below the depth of the engraving. The crystalline structure dislocation that is produce by stamping and that is responsible for revealing the original erased marks by chemical etching and other methods cannot be expected to be much with engraved mark and it can be only minimal. Hence, the restorations of erased engraved marks are considered difficult in practice.

OBJECTIVES OF THE STUDY

In recent years, engraved serial numbers are increasingly used in the chassis and engine number of cars and of the guns (Gregory S. Klees 2004). Hence the present work is concerned with the restoration of erased engraved marks on steel surfaces following this objective:

- to identify the most sensitive metallographic reagent that can be used to reveal plastically deformed layers of the metal by determining the maximum depth below the original engraving to which the identified reagent is sensitive in restoring the erased engraved marks on steel surfaces

METHODOLOGY

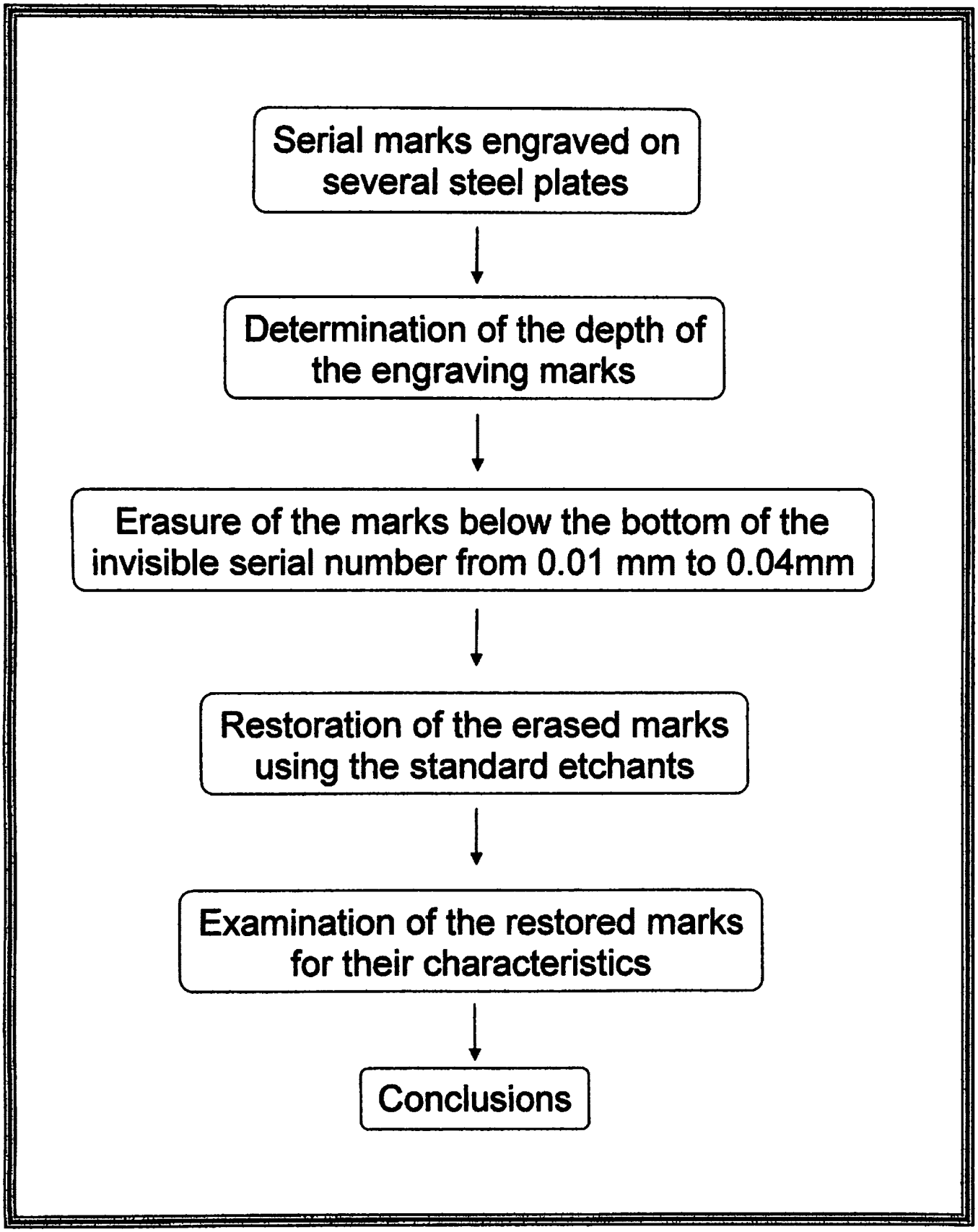

Chart 1 : Flow Chart showing step-by-step process of the work.

Engraved Plates

A number of steel plates of dimension of 10 cm wide, 3.5 cm long and 1.5mm thick were selected. A large number of these plates were then engraved with a combination of alpha-numeric characters W84 using a computerized mechanical engraving machine known as Gravograph. The machine is able to make reproducible engraving marks on each plate, where the maximum depth of the indentation produced on each plate is 0.03 mm. The characters were chosen as they contain both straight and curved surface. The plates were then labelled appropriately with specific mark designed to it, since the individual plate will be erased to different depth and will be then treated with different etching solution.

Figure 2 : A plate engraved with alpha-numeric characters W84